International Journal of Agricultural
Science and Research (IJASR)
ISSN (P): 2250-0057; ISSN (E): 2321-0087
Vol. 4, Issue 2, Apr 2014, 97-104

TRANS STELLAR
• Journal Publications • Research Consultancy

ASSOCIATION ANALYSIS OF DROUGHT AND YIELD RELATED TRAITS IN F_2 POPULATION OF MOROBEREKAN/IR64 RICE CROSS UNDER AEROBIC CONDITION

MANJAPPA[1], G. UDAY[2] & SHAILAJA HITTALMANI[3]

Department of Genetics and Plant Breeding, UAS, GKVK, Bangalore, Karnataka, India

ABSTRACT

Present study was performed to determine the association between drought and yield related traits in F_2 population of Moroberekan/IR64 rice cross. Results showed that harvest index (r = 0.30), biomass yield (r = 0.78), panicle weight (r = 0.58), panicle length (r= 0.34) and number of productive tillers plant^{-1} (r = 0.62) correlated significantly with grain yield, while grain yield was negatively associated with leaf rolling (r= -0.19). Path coefficient analysis revealed that harvest index and biomass had direct effect on grain yield (0.320 and 0.566 respectively). The results obtained during present investigation revealed that harvest index, biomass yield, number of productive tillers plant^{-1} and leaf rolling could be used as selection criteria for high grain yield and drought resistance in segregating populations of rice.

INTRODUCTION

Rice (*Oryza sativa* L.) is the world's most important food crop and energy source for about half of the world's population and ranks second in production after maize. In India rice has covered 43.65 million hectare area with the production and productivity of 105.30 million tones and 2372 kg/hectare respectively (DES, 2011-12). Moreover it is the most important grain with regard to human nutrition and caloric intake, providing more than one fifth of the calories consumed worldwide by the human species. It plays a very important role in the food security of many nations (Khush 2005).

Rice is unique in its ability to grow in a wide range of hydrologic environments. Rice is cultivated in several ecosystems like upland, rainfed lowland, flood prone, and irrigated. It frequently faces abiotic stresses in all these ecosystems except irrigated ecosystem. Rainfed upland and rainfed lowland ecosystems contribute only 21% of the total production from 38% of the cropped area. Drought limits the rice production by preventing it from expressing their full genetic potential. Grain yield can be drastically reduced if drought stress occurs during flowering. Worldwide, drought affects approximately 23 million ha of rainfed rice. Among different rainfed regions, eastern India, with around 13.6 million ha of drought-prone area, is the largest.

The global reduction in rice production due to drought averages 18 M t annually (O'Toole, 2004). In India severe drought has witnessed during 2002 and 2009 caused a significant yield reduction in rice. In 2002 compared to the previous year, rice production fell by 21.5 million tons, whereas drastic reduction in total rice production from 99.4 million tonnes in 2008-09 to 89.1 million tonnes in 2009-10, total rice production declined by approximately 10.02 million tons (Anon., 2010).

Phenotypic correlation of grain yield, yield and drought related traits provide the information on magnitude and direction of association (Sunderraj *et al.* 1972). This information of association of various traits with yield and drought

tolerance in early segregating generation would help immensely to continue selecting plants that are strongly related to yield and drought tolerance in next generation. Path coefficient analysis is a standardized partial regression coefficient that measures the direct influence of one trait upon another and permits the separation of correlation into components of direct and indirect effects (Board *et al.*, 1997). It provides information of influence of each trait on yield under drought stress directly and indirectly and enable the breeders to prioritize the genetic attributes according to their contribution.

Therefore, the present study was conducted to evaluate the response of F_2 segregating population under low moisture stress condition for yield and drought related characters and to find out all the morphological parameters and drought related traits that are more effective in favor of plant under low moisture stress.

MATERIAL AND METHODS

With the intention of combining deep rooted nature and drought tolerant characters of Moroberekan, a *japonica* variety with the high yielding ability of IR64, an *indica* variety, crossing was conducted between Moroberekan and IR64 during dry season 2011. F_1's were confirmed by SSR marker and true F_1's were selfed during kharif 2011. F_2 seeds were used for sowing in the nursery during dry season 2012. Twenty eight days seedlings of F_2 population of Moroberekan/IR64 of size 250 were transplanted along with their parents and drought resistant check Azucena and susceptible check IR50 during dry season 2012.

The experiment was conducted in K block, UAS, GKVK, Bangalore, representing the eastern dry zone which is located at the latitude of 12^{o} 58' North; longitude 77^{o} 35' East and altitude of 930 meters above mean sea level. Spacing maintained for F_2 individuals was 25cm X 25cm, one plant per hill was maintained. Recommended cultural practices for aerobic rice were carried out grow the crop (www.aerobicrice.org). Fertilizer was applied at the rate of 100 (N): 50 (P): 50 (K): 20 (Zn): 12 (Fe) kg/ha, respectively. Irrigation was given once in three days for the crop under aerobic condition.

Low moisture stress was induced during the transition period of vegetative stage to reproductive stage by withholding irrigation between 70^{th} to 90^{th} days after sowing and during the stress period rainfall has not occurred. Scoring for drought symptoms (leaf rolling) was made on last day of stress period.

Phenotypic observations were made on morphological, grain yield and drought related traits are listed in table 1.

The plant height was recorded six times on each F_2 individual plant at different interval of time during vegetative growth stage up to stabilization of plant height. Plant vigor was calculated by following the compound growth rate formula (Sikka and Vaidya, 1985) by considering all six plant heights. Leaf rolling and culm angle was scored as per the Rice Standard Evaluation System (IRRI, 2002). Phenotypic correlation coefficient was computed by using the formula given by Sunderraj *et al.* (1972) and path analysis was performed by following the method suggested by Dewey and Lu (1959).

RESULTS AND DISCUSSIONS

The degree of association among the characteristics is an important factor, particularly yield, complex character, show low effectiveness to direct selection. Hence association analysis was carried out to determine the direction of selection and number of characters to be considered in improvement of grain yield. Phenotypic correlation coefficients among all traits were estimated in F_2 population derived from Moroberekan/IR64 rice cross.

Association between grain yield per plant and its component characters are revealed as follow. Grain yield

exhibited strong significant positive association with number of productive tillers per plant (0.62) (Vaishali, 2003), panicle weight (0.56), biomass yield (0.78) and total tiller number (0.45) and showed moderate significant positive association with harvest index (0.30), panicle length (0.34), test weight (0.24), number of spikelets per panicle (0.34), plant height (0.38) and leaf width (0.23) (Bagali, *et al*., 1999; Girish, 2006; Gupta *et al*., 1999; Kiani and Nematzadeh, 2012). Grain yield per plant has shown non-significant negative association with days to flowering (-0.07) and days to maturity (-0.04). Whereas, association ship of grain yield with drought related traits under low moisture stress exhibited significant negative correlation with leaf rolling (-0.19), significant positive correlation with spikelet fertility (0.31) and panicle exsertion (0.225) (Muthuramu *et al.,* 2010; Venkataramana *et al*., 1999; Zulqarnain *et al*., 2012) and no significant correlation with plant vigor.

This result clearly suggests that, priority should be given to number of productive tillers per plant, panicle weight, biomass yield and total tiller number followed by other associated traits while making selection for yield improvement. Leaf rolling is the most important criteria found useful in assessing levels of drought tolerance in large scale screening (Chang *et al*., 1974). Therefore selection for high grain yield per plant with high spikelet fertility and lower leaf rolling under low moisture stress is useful to get drought tolerant genotypes. The relationship between yield and its main contributing traits, in segregating population of rice, has been studied by several researchers (Basavaraj *et al*., 1997; Kumar *et al.,* 2009; Reddy and Ramachandraiah, 1990; Surek and Beser, 2005; Venkataramana and Shailaja, 1999; Venkataramana and Shailaja, 2000; Yogameenakshi and Vivekanandan).

Plant height exhibited significant positive association with panicle length (0.58), panicle weight (0.51), biomass yield (0.42) and test weight (0.39), plant vigor (0.23) (Shivapriya, 2004). Days to flowering exhibited significant positive association with days to maturity (0.88) while, it showed significant negative association with spikelet fertility (-0.28) and number of productive tillers (-0.25). Number of productive tillers showed significant positive association with biomass yield (0.65) and spikelet fertility (0.23). Panicle length showed significant positive association with biomass yield (0.39) and test weight (0.25) (table 2). From the above result it has observed that biomass has associated with many other yield attributing traits (Shivapriya, 2004), so we can consider biomass yield as major criteria while selection for grain yield.

Leaf rolling recorded significant positive association with days to flowering (0.15) and days to maturity while, it exhibited significant negative correlation with total tiller number (-0.19), productive tiller number (-0.24) and biomass yield (-0.26) (Selvaraj *et al.,* 2010). This clearly indicates leaf rolling decreases yield potential of the genotypes under low moisture condition via delayed flowering, lower total tillers and productive tiller numbers and biomass yield. With the assumption of negative association between leaf width and leaf rolling, correlation study was carried out, but result was no correlation.

Panicle exsertion exhibited significant positive correlation with productive tiller number (0.16), biomass yield (0.23), panicle weight (0.21), panicle length (0.25), spikelet fertility (0.34) and plant vigor (0.17) and negatively correlated with days to flowering (-0.24) and culm angle (-0.15). It has been reported that drought stress applied at the beginning of the reproductive stage usually results in a delay in flowering (Saini and Westgate, 2000) this is mainly due to slowed elongation of the panicle and supporting tissues (Lafitte *et al*., 2004). Slow panicle elongation means that anthesis may occur while part of the panicle is still within the leaf sheath, unexerted spikelets will be sterile (Ji *et al*., 2005).

Therefore greater the delay in flowering, the greater the yield reduction due to drought. Hence current correlation study indicates that, early flowering will have better panicle exsertion which in turn increases spikelet fertility, panicle weight and finally grain yield per plant (0.225) under drought condition, which is in agreement with the above statements made by various researchers. Plant vigor exhibited significant positive association with days to flowering (0.26) days to maturity (0.24), panicle length (0.15) while, it showed negative association with tiller number (-0.15) and number of spikelets per panicle (-0.13). Spikelet fertility exhibited significant positive association with biomass yield (0.18) and harvest index (0.23). Result suggest that, breeder can make selection for drought resistance genotypes in further generation by considering leaf rolling, panicle exsertion and spikelet fertility as a main criteria.

Estimates of Direct and Indirect Effects of Yield Attributing Characters

Path coefficient analysis of yield components revealed that number of productive tillers per plant showed positive direct effect of 0.219 on grain yield per plant (table 3). However, it showed strong positive indirect effect via biomass yield (0.373) and negative indirect effect via tiller number (-0.032) and panicle length (-0.006) on grain yield per plant, bringing the total correlation to 0.628. Results on importance of direct effect of panicles per plant were reported by several researchers (Bagheri *et al.,* 2011; Gupta *et al.*, 1999; Kumar, 1992; Madhavilatha *et al.,* 2005; Shivapriya, 2004; Yadav and Bhushan, 2001; Yogameenakshi and Vivekanandan, 2010).

Plant height exhibited positive direct effect of 0.044 on grain yield per plant. However, it showed strong positive indirect effect via biomass yield (0.236), panicle weight (0.108), and negative indirect effect via panicle length (-0.046), harvest index (-0.028) and panicle exsertion (-0.002) on grain yield per plant. Phenotypic correlation (0.386) between yield per plant and plant height was highly positive. It indicates that plant height would not be reliable criteria for improving yield per plant (table 2).

Total tiller number exhibited negative direct effect of -0.042 on grain yield per plant. However, it showed strong positive indirect effect via biomass yield (0.333), number of productive tillers per plant (0.164) and negative indirect effect via panicle length (-0.003) and test weight (-0.003) on grain yield per plant. Phenotypic correlation (0.452) between yield per plant and total tiller number was highly positive. It indicates that total tiller number would not be reliable criteria for improving yield per plant (table 2).

Panicle weight showed positive strong direct effect of 0.210 on grain yield per plant (Bagali *et al*., 1999). However, it showed strong positive indirect effect via biomass yield (0.243), spikelet fertility (0.028), number of spikelets per panicle (0.027) and negative indirect effect via panicle length (-0.043) and panicle exsertion (-0.001) on grain yield per plant. Phenotypic correlation (0.561) between yield per plant and panicle weight was highly positive (table 2). It indicates that panicle weight may be used as a reliable criteria for improving yield per plant.

Panicle length showed negative direct effect of -0.078 on grain yield per plant. However, it showed strong positive indirect effect via biomass yield (0.223), panicle weight (0.116), number of productive tillers (0.04) and negative indirect effect via harvest index (-0.015) and panicle exsertion (-0.001) on grain yield per plant.

Test weight showed positive direct effect of -0.043 on grain yield per plant. However, it showed positive indirect effect via panicle weight (0.076), spikelet fertility (0.020) and negative indirect effect via panicle length (-0.019) and harvest index (-0.016) on grain yield per plant. Biomass yield exhibited strong positive direct effect of 0.566 on grain yield

per plant. Indirect effect via number of productive tillers (0.144) and panicle weight (0.090) was positive and countered the negative indirect effect via panicle length (-0.031) and total number of tillers (-0.031) resulting in strong positive phenotypic correlation (0.787) with the yield per plant. It indicates that biomass yield may be used as reliable criteria for improving yield per plant (table 2).

Harvest index showed strong positive direct effect of 0.320 on grain yield per plant (Bagali *et al.*, 1999; Girish, 2006; Vekataraman and Shailaja, 2000). Indirect effect via panicle weight (0.007), panicle length (0.004), and productive tiller number (0.004) is positive and countered the negative indirect effect via spikelet fertility (-0.002) and number of spikelets per panicle (-0.003) resulting in strong positive association with yield (0.304). It indicates that harvest index may be used as reliable criteria for improving yield per plant (table 2).

Number of spikelets per panicle showed positive direct effect of 0.063 on grain yield per plant. However, it showed strong positive indirect effect via biomass yield (0.181), panicle weight (0.090), and negative indirect effect via panicle length (-0.018) and harvest index (-0.014) on grain yield per plant. Leaf rolling showed null direct effect of 0.00 on grain yield per plant. However, it showed positive indirect effect via tiller number (0.008), harvest index (0.025), and negative indirect effect via biomass yield (-0.149) on grain yield per plant. This clearly indicates that leaf rolling is not have any direct effect on yield.

Panicle exsertion showed negative direct effect of -0.004 on grain yield per plant. However, it showed strong positive indirect effect via biomass yield (0.130), panicle weight (0.044) and negative indirect effect via harvest index (-0.016) on grain yield per plant.

Spikelet fertility showed positive direct effect of 0.053 on grain yield per plant. Indirect effect via panicle weight (0.113) and 100 seed weight (0.016) was positive and countered the negative indirect effect via panicle length (-0.012) and total number of tillers (-0.005) resulting in its strong and significant association with yield (0.315). This indicates that, spikelet fertility may be used as reliable criteria for improving yield per plant under drought stress. Since most of the drought related traits are exhibiting high indirect effect than direct effect on yield, indicates that these would not be contributed to yield directly. However, association study suggests these traits can be used along with yield contributing traits as reliable criteria for selecting high yielding drought resistance genotypes under stress (table 2).

CONCLUSIONS

The results suggest that the principle characters responsible for yield in this F_2 population are biomass yield, harvest index, total tiller number, productive tillers per plant, panicle weight and panicle length and important drought related traits are leaf rolling, panicle exsertion and spikelet fertility. Hence simultaneous selection on these traits will help to improve yield under drought condition in segregating generation.

REFERENCES

1. Anonyomous, 2010, *Economic Survey of India - 2009-2010*. Ministry of Finance, Government of India, New Delhi.
2. Bagali, P. G., Shailaja Hittalmani and Shashidhar H.E., 1999. Character association and path coefficient analysis in *indica x japonica* doubled haploid population of Rice. *Oryza* **36**(1): 10-12.

3. Bagheri, N., Babaeian-Jelodar, N. and Pasha, A., 2011, Path coefficient analysis for yield and yield components in diverse rice (*Oryza sativa* L.) genotypes. *Bih. Biol.* **5**:32-35.

4. Basavaraja, P., Rudradhya, M. and Kulkarni, R. S., 1997, Genetic variability, correlation and path analysis of yield components in two F_4 population of fine grained rice. *Mysore J. Agric. Sci.* **1**:1-6.

5. Board, J. E., Kang, M. S. and Hartville, B. G., 1997, Path analyses identify indirect selection criteria for yield of late planted soybean. *Crop Sci.* **37**:879-884.

6. Chang, T. T., Loresto, G. C. and Tagum, P. O., 1974, Screening rice germplasm for drought resistance. *SABRAO J.* **6**(1): 9-16.

7. DES, 2011-12, Directorate of Economics and statistics, Department of Agriculture and Cooperation.

8. Dewey, D. R. and Lu, M. R., 1959, A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agron. J.* **51**: 515-518.

9. Girish, T. N., Gireesha, T. M., Vaishali, M. G., Hanamareddy, B. G. and Shailaja Hittalmani, 2006, Response of a new IR50/Moroberekan recombinant inbred population of rice (*Oryza sativa* L.) from an *indica x japonica* cross for growth and yield traits under aerobic conditions.

10. Gupta, K. R., Panwar, D. V. S. and Rakesh kumar, 1999, Character association in segregating population in basmati rice, *Oryza.* **36** (1): 16-19.

11. http://www.aerobicrice.org

12. IRRI, 2002, standard evaluation system of rice (SES). International rice research institute.

13. Ji, X. M., Raveendran, M., Oane, R., Ismail, A., Lafitte, H. R., Bruskiewich, R., Cheng, S. H. and Bennet, J., 2005, Tissue-specific expression and drought responsiveness of cell-wall invertase genes of rice at flowering. *Pl. Mol. Bio.* **59**:945-964.

14. Khush, G. S., 2005, What it will take to feed five billion rice consumers by 2030. *Pl.Mol.Bio.* **59**:1-6.

15. Kiani, G. and Nematzadeh, G., 2012, Correlation and Path Coefficient Studies in F_2 Populations of Rice. *Not. Sci. Biol.* **4**(2):124-127

16. Kumar, C. R. A., 1992, Variability and character association studies in upland rice. *Oryza.* **29**:31-34.

17. Lafitte, H. R., Ismail, A. and Bennet, J., 2004, Abiotic stress tolerance in rice for Asia: progress and the future, in *New directions for a diverse planet: Proceedings of the 4th International Crop Science Congress*, ed. by Fischer, T., Turner, N., Angus, J., McIntyre, L., Robertson, M., Borrell, A. and Lloyd, D., Brisbane, Australia.

18. Madhavilatha, L., Reddi, M., Suneetha, Y., Srinivas, T., 2005, Genetic variability, correlation and path analysis for yield and quality traits in rice (*Oryza sativa* L.). *Res Crops* **6**(3):527-534.

19. Muthuramu, S., Jebaraj, S. and Gnanasekaran, M., Association analysis for drought tolerance in rice (*Oryza sativa* L.), *Research Journal of Agricultural Sciences* 2010, **1**(4): 426-429

20. O'Toole, J. C., 2004, Rice and water: the final frontier, in *The first international conference on rice for the future*, Ed. The Rockefeller Foundation, Bangkok, Thailand, p 26.

21. Ram, T., 1992, Character association and path coefficient analysis in rice hybrids and their parents. *J Andaman Sci Assoc.* **8**:26-29.

22. Reddy, C. D. R. and Ramachandraih, D, 1990, Genotypic correlation of components of yield in parents and their F_2s in rice (*Oryza sativa* L.). *Orissa J. Agri. Res.***3**:136-142.

23. Saini, H. S. and Westgate, M. E., 2000, Reproductive development in grain crops during drought. *Advances in Agronomy* **68**:59-95.

24. Selvaraj, M. G., Manikanda, N. B., Satheesh K. S., Ramasubramanian, T., Zhu C., Jeyaprakash, P., Senthil, A. and Chandra Babu, R., 2010, Molecular mapping and location of QTLs for drought-resistance traits in *indica* rice (*Oryza sativa* L.) lines adapted to target environments. *Acta Physiol Plant.* **32**:355–364.

25. Shivapriya, M., 2004, Evaluation of IR50/Moroberekan recombinant inbred lines (RILs) for drought and blast resistance and parental polymorphism using DNA markers in rice (*Oryza sativa* L.). *Ph. D Theses*, Univ. Agri. Sci., Bengaluru, India.

26. Sikka, B. K. and Vaidya, C. S., 1985, Growth rates and cropping pattern changes in agriculture in Himachal Pradesh, *Agricultural Situation in India,* **39**(11) : 843-84.

27. Sunderraj, N., Nagaraj, S., Vekara Ramu, M. N. and Jagannath, M. K., 1972, Designs and analysis of field experiments. Uni. Agri. Sci., Hebbal, Bangalore.

28. Surek, H. and Beser, N., 2005, Selection for grain yield and its components in early generation in rice (*Oryza sativa* L.). *Trakia Univ. J. Sci*. **6**:51-58.

29. Vaishali, M. G., 2003, DNA marker assisted mapping of blast and yield loci, graphical genotyping and candidate gene analysis in rice (*Oryza sariva* L). *Ph. D Theses*, Univ. Agri. Sci., Bengaluru, India.

30. Venkataramana P. and Shailaja Hittalmani, 1999. Association analysis in F_2 populations of three intra-varietal crosses in Rice (*Oryza sativa* L.). *Crop. Res*., **18**(1): 89-92.

31. Venkataramana P. and Shailaja Hittalmani, 2000. Path analysis in F_2 segregating populations of rice (*Oryza sativa* L.). *Crop Res.,* **20**(2): 206-208.

32. Yadav, R. S. and Bhushan, C., 2001, Effect of moisture stress on growth and yield in rice genotypes. *Indian J. Agri. Res.,* **2**:104-107.

33. Yogameenakshi, P. and Vivekanandan, P., 2010, Association analysis in F_1 and F_2 generations of rice under reproductive stage drought stress. *Electron. J. Plant Breed.* **1**(4):890-898.

34. Zulqarnain Haider, Abdus Salam Khan and Samta Zia, 2012, Correlation and path coefficient analysis of yield components in rice (*Oryza sativa* L.) under simulated drought stress condition, *American-Eurasian J. Agric. & Environ. Sci.,* **12** (1): 100-104.

APPENDICES

Table 1: List of Observations Made on F_2 Population of Moroberekan/IR64 Rice Cross and Their Abbreviations and Standard Units Used in the Current Study

Sl. No.	Abbreviations	Character	Standard Units
1	PHT	Plant height	Cm
2	LW	Leaf width	Mm
3	DF	Days to Flowering	Days
4	DM	Days to maturity	Days
5	TN	Total tiller number/plant	Number
6	PTN	Productive tillers/plant	Number
7	CA	Culm Angle/ Plant type	Degree
8	PW	Panicle weight	G
9	PL	Panicle length	Cm
10	HI	Harvest index	Ratio
11	TW	Test weight	G
12	NOS	Number of spikelets/panicle	Number
13	BY	Biomass yield	G
14	YLD	Grain weight/plant	G
15	PEN	Panicle exsertion	±
16	LR	Leaf rolling score	Score
17	SF	Spikelet fertility	%
18	PV	Plant vigor	%

Table 2: Phenotypic Correlation Coefficients among Seventeen Morphological, Yield and Drought Related Traits in F_2 Population of Moroberekan/IR64 Rice Cross Evaluated Under Aerobic Condition During Dry Season 2012.

	LW	PHT	PV	DF	DM	TN	PTN	PW	PL	SW	NOS	SF	BY	HI	CA	YLD
LR	-0.11	0.02	0.04	**0.15***	0.11	**-0.19****	-0.24**	-0.05	0.02	-0.05	-0.04	-0.09	**-0.26****	0.07	0.01	**-0.19****
LW	1	0.16*	**-0.21****	**-0.15***	-0.11	0.05	0.12	**0.29***	**0.13***	**0.259***	**0.17****	0.11	**0.25****	0.06	0.02	**0.23****
PHT		1	**0.23****	-0.08	-0.07	-0.06	0.11	0.51**	0.58**	**0.39****	**0.25****	**0.23****	**0.42****	0.08	0.12	**0.38****
PV			1	**0.26****	**0.24****	**-0.15***	-0.08	0.03	**0.15***	0.03	-0.13*	0.12	-0.07	0.05	**0.14***	-0.02
DF				1	**0.88****	-0.09	**-0.25****	-0.11	-0.09	**-0.21****	**0.14***	**-0.28****	0.06	0.04	**0.16***	-0.07
DM					1	0.01	**-0.16***	-0.12	-0.06	**-0.21****	**0.13***	**-0.29****	-0.02	0.05	-0.1	-0.04
TN						1	0.75**	0.02	0.042	-0.08	**0.13***	0.11	**0.58****	**-0.03**	**0.19****	**0.45****
PTN							1	**0.23****	**0.18****	0.08	**0.15***	**0.23****	**0.65****	**0.01**	**0.17****	**0.62****
PW								1	**0.55****	**0.36****	**0.43****	**0.54****	**0.42****	**0.03**	0.00	**0.56****
PL									1	**0.25****	0.22*	**0.15***	**0.39****	0.04	0.03	**0.34****
SW										1	-0.03	**0.37****	**0.19****	0.04	0.03	**0.24****
NOS											1	0.01	**0.32****	0.04	0.07	**0.34****
SF												1	**0.18****	-0.03	-0.02	**0.31****
BY													1	-0.04	**0.21****	**0.78****
HI														1	-0.07	**0.30****
CA															1	0.10

*,** significant at 0.05 and 0.01 level.

Table 3: Direct and Indirect Effects of Morphological, Yield and Drought Related Traits on Yield in F_2 Population of Moroberekan/IR64 Rice Cross

	PHT	LW	LR	TN	PTN	PW	PL	PEN	TW	SF	BY	HI	NOS	r
PHT	**0.044**	0.000	0.000	0.003	0.026	0.108	-0.046	-0.002	0.016	0.012	0.236	-0.028	0.016	0.386**
LW	0.007	**0.000**	0.000	-0.002	0.025	0.062	-0.010	0.000	0.011	0.006	0.143	-0.021	0.011	0.231**
LR	0.001	0.000	**0.000**	0.008	-0.053	-0.010	-0.002	0.001	-0.002	-0.005	-0.149	0.025	-0.003	-0.189**
TN	-0.003	0.000	0.000	**-0.042**	0.164	0.005	-0.003	0.000	-0.003	0.006	0.333	-0.011	0.008	0.452**
PTN	0.005	0.000	0.000	-0.032	**0.219**	0.047	-0.014	-0.001	0.003	0.012	0.373	0.005	0.009	0.628**
PW	0.023	0.000	0.000	-0.001	0.050	**0.210**	-0.043	-0.001	0.015	0.028	0.243	0.011	0.027	0.561**
PL	0.026	0.000	0.000	-0.002	0.040	0.116	**-0.078**	-0.001	0.011	0.008	0.223	-0.015	0.014	0.341**
PEN	0.019	0.000	0.000	-0.002	0.036	0.044	-0.014	**-0.004**	0.011	0.019	0.130	-0.016	0.002	0.225**
TW	0.017	0.000	0.000	0.003	0.018	0.076	-0.019	-0.001	**0.043**	0.020	0.108	-0.016	-0.002	0.246**
SF	0.010	0.000	0.000	-0.005	0.050	0.113	-0.012	-0.001	0.016	**0.053**	0.101	-0.010	0.001	0.315**
BY	0.018	0.000	0.000	-0.025	0.144	0.090	-0.031	-0.001	0.008	0.009	**0.566**	-0.012	0.020	0.787**
HI	-0.004	0.000	0.000	0.001	0.004	0.007	0.004	0.000	-0.002	-0.002	-0.022	**0.320**	-0.003	0.304**
NOS	0.011	0.000	0.000	-0.005	0.032	0.090	-0.018	0.000	-0.001	0.001	0.181	-0.014	**0.063**	0.341**

Residual effect (R) = 0.427606